PATENT SPECIFICATION

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DRAWINGS ATTACHED.

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COMPLETE SPECIFICATION.

Apparatus for Contacting a Liquid with a Liquid or a Particulate Solid.

I, MINISTER OF AVIATION (formerly Minister of Supply), London, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to apparatus which provides for the contacting of two components of different densities which may be two immiscible or partly immiscible liquids or of a liquid with a particulate solid as occurs in a wide variety of industrial processes such as, for example, leaching or extraction, washing or chemical reaction processes. The invention is concerned with apparatus of this type in which the desired interaction between the two components takes place by means of a counter-current flow of the two components in a series of vessels arranged horizontally or substantially horizontally.

Various forms of apparatus have been previously proposed or used which employ a series of mixing and separating vessels in which the two components are separated into two layers, some having relatively complicated arrangements for pumping or raising the level of one of the components at various stages to maintain an onward flow of the components through the apparatus.

It is an object of the invention to provide for the contacting of two components in a counter-current liquid flow system, apparatus which does not employ any power-driven device (other than mixing devices in the mixing vessels) for maintaining the counter-current flow between mixing vessels and which is relatively simple and compact in design and versatile and efficient in operation.

The present invention provides an apparatus having vessels between mixing vessels in which the counter-current flow of the two components is arranged to take place without separation into two layers, functioning on the spray-tower principle wtih one component as a discontinuous phase passing as liquid droplets or solid particles through the other continuous phase component flowing counter-currently. These vessels in which the counter-current flow takes place between two mixing vessels will be called counter-current displacement vessels as in these vessels a dynamic counter-current relative displacement causes the two components to flow in opposite directions with no or only a slight incidental separation in separate layers.

Each counter-current displacement vessel arranged between two mixing vessels has an opening connecting it to one of the neighbouring mixing vessels at a low level so that the denser component which descends to the bottom of the counter-current displacement vessel may flow to this mixing vessel and each displacement vessel has an opening connecting it to the other neighbouring mixing vessel at a high level so that the lighter component which rises to the top of the displacement vessel may flow to this other mixing vessel.

The counter-current flow in the displacement vessels is a counter-displacement of the two components maintained by gravity, the denser component falling and the lighter component rising within the vessels until the

connecting openings to the adjacent mixing vessels are reached in each case. In the mixing vessels, the counter-current flow is maintained by the action of stirring or mixing devices which, by intimately intermixing the contents, act to move upwards the denser component introduced at the lower level and move downwards the lighter component introduced at the upper level.

It is a fundamental feature of the invention that the mixing vessels and counter-current displacement vessels are inter-connected and the mixing devices function so that the mixing action is effective throughout the whole height of each mixing vessel between its upper and lower inter-connecting openings and causes the mixture to be swept through these openings and across the upper and lower regions of the connected counter-current displacement vessels. As a result the counter-current flow is made continuous from vessel to vessel.

Any desired number of alternate mixing and counter-current displacement vessels may be connected in series so that with the liquid surface at substantially the same level throughout, the denser component may pass in one direction through the series of vessels while the lighter component passes through in the opposite direction. Continuous operation of the apparatus may then be readily established by supplying the two components appropriately one at each end of the series of vessels and drawing off the components at the opposite ends after they have passed through the apparatus.

According to the invention, an apparatus for counter-currently contacting two immiscible or at least partly immiscible components of different densities, one component being a liquid and the other being a second liquid or a particulate solid, comprises a single series of inter-connected vessels which may be filled with the components and which are alternately mixing vessels and upright counter-current displacement vessels, each mixing vessel having only two inter-connecting openings of which a lower opening connects the base region of each mixing vessel to the base region of the adjacent counter-current displacement vessel in the series in one direction and an upper opening connects each mixing vessel to the adjacent counter-current displacement vessel in the series in the other direction near to the level of the liquid surface when in the vessels, and a mixing device in each mixing vessel for mixing the components throughout the whole height of the mixing vessels whereby in operation the mixed components are swept through the inter-connecting opening into and across the adjacent counter-current displacement vessels and counter-current displacement of the two components takes place in the counter-current displacement vessels by counter-current movement of droplets or particles of one component distributed freely in the other component so that the two components are displaced through the series of vessels in opposite directions.

When the apparatus is operating continuously, the leading mixing vessel in the series is supplied with the lighter component while the last mixing vessel is supplied with the denser component, and the lighter component is drawn off from the last mixing vessel in the series while the denser component is drawn off from the leading mixing vessel.

The mixing vessels are provided with mixing or stirring devices in the form of agitators such as flat gate-paddle impellers which do not produce any, or produce only a slight, resultant up or down movement of the liquid in the mixing vessels so that the onward movement of each component is not materially opposed or assisted.

Either the lighter or denser component may be the continuous phase of the system while the other component is the discontinuous phase, except if one component is a particulate solid this would be the discontinuous phase.

The connecting openings between successive vessels in the plant may be in various forms which permit an adequate counter-current flow to take place. In a compact form of apparatus, adjacent vessels in the series are constructed with common walls and the inter-connecting openings are formed in or are at the end of the common walls. Alternatively, the adjacent vessels may consist of individual cylindrical or rectangular vessels connected together by short, straight pipes of rectangular or circular cross-section which form the inter-connecting openings. In a further modification, each counter-current displacement unit, with its connecting openings, is in the form of a single S-shaped pipe of suitable cross-sectional area, connecting the bottom of one mixing vessel with the top of the succeeding mixing vessel.

The counter-current displacement vessels may take the form of simple unpacked spray columns, packed towers, orifice plate towers, or any suitable form of extraction tower in which the effect of gravity causes the denser component to be displaced downwards and the lighter component to be displaced upwards.

The invention will now be more particularly described by way of example in the course of the following description of three of the many possible plant constructions incorporating the fundamental principles of the invention. The description will be made with reference to Figures 1, 2 and 3 of the drawings accompanying the Provisional

Specification and which are sectioned longitudinal views of the three plants.

Figure 1 illustrates a plant consisting essentially of a long rectangular vessel subdivided by vertical cross-walls or baffles into a series of vessels or compartments so that adjacent vessels in the series are constructed with common walls. These vessels are mixing vessels M1 to M5 which are positioned alternately with counter-current displacement vessels C1 to C4.

The wall on one side of each mixing vessel M1 to M5 does not extend to the bottom of the vessel and leaves a rectangular opening linking the base of the mixing vessel with the base of the adjacent counter-current displacement vessel through which the lower layers of liquid in the two vessels can intermix. On the opposite side of each mixing vessel the top of the wall is below the surface of the liquid leaving an opening between the top of the mixing vessel and the top of the other adjacent counter-current displacement vessel through which the surface layers can intermix.

Figure 2 illustrates a plant consisting of individual cylindrical or rectangular vessels forming alternate mixing vessels M1 to M5 and counter-current displacement vessels C1 to C4 linked together by short straight pipes as shown of rectangular or circular cross-sections which form communicating channels connecting the base of each mixing vessel with the base of an adjacent displacement vessel, and connecting the upper region of each mixing vessel with the upper region of the other adjacent displacement vessel.

Figure 3 illustrates a similar plant modified so that each counter-current displacement vessel and its connecting openings is in the form of a single S-shaped pipe of suitable cross-sectional area, connecting the bottom of one mixing vessel with the upper region of the succeeding mixing vessel.

In both plants illustrated in Figures 2 and 3 the communicating channels or openings between the mixing vessels M1 to M5 and counter-current displacement vessels C1 to C4 will need to be short and of sufficient cross-sectional area for the agitation in the mixing vessels to be carried across into the base region of the appropriate neighbouring displacement vessels.

In all three embodiments, the distribution of the discontinuous phase in the counter-current displacement vessels may be assisted by the addition of a suitably designed distributor, for example a perforated plate with an up or down comer, situated across the lower or upper region of each displacement vessel according to whether the lighter or heavier component respectively is the discontinuous phase.

The impellers for the mixing vessels shown diagrammatically as R1 to R5 in each of Figures 1 to 3, should provide reasonably intimate mixing through the depth of the vessel without producing any significant overall upward or downward flow. Flat-bladed turbine or gate-paddle impellers may be used; flat small bladed turbine impellers operating at relatively high speeds being suitable where a high degree of agitation is required, while large flat gate-paddle impellers operating at low speeds are suitable where intimate mixing is not so essential to the process. In any case, reasonably uniform agitation is necessary vertically throughout the whole contents of the mixing vessel for effective counter-current operation. In a plant using rectangular mixing vessels and common connecting walls as illustrated in Figure 1, agitators R1 to R5, centrally situated in the contents of each mixing vessel, are effective without any baffling. In the case of cylindrical mixing vessels, some form of baffling such as vertical baffling, is necessary which will not produce any marked overall upward or downward flow.

If flat gate-paddle impellers are used, for example, in a plant as shown in Figure 1 the complete length of each impeller blade should be about half the width of the mixer vessel and the height of each impeller about half the depth of the liquid. The speed of the impeller in r.p.m. for most systems should then be of the order of 200/width of, or mean norizontal distance across, the mixer vessel in feet.

At each end of the series of vessels M1 to M5 and C1 to C4 in each plant are end separating vessels SL and SH which are arranged to collect the lighter and denser components respectively which are then drawn off through outlet pipes LL and LH respectively.

The height of the outlet pipe for the continuous phase is approximately that of the surface level of the liquid. The height of the outlet pipe for the discontinuous phase will more largely depend upon the relative densities of the two phasés and may either be set from density calculations or made adjustable and set as required during operation of the plant.

With the end separator outlet pipes LL and LH at suitable heights, the plants can operate with either the heavier or lighter component as the continuous phase depending upon the relative concentration of the two components in the plant. The relative concentration depends upon a number of factors including the nature of the liquids, the size and shape of the counter-current displacement vessels and the communicating openings, and the action of the mixing impellers which may be arranged to slightly counter the flow of one component and so increase its concentration.

In all three plants the action is as follows.

The lighter component is supplied to the mixing vessel M1 and passes in one direction through the series of vessels to the vessel M5 as shown by the broken arrow lines, while the heavier component is supplied to the mixing vessel M5 and passes in the reverse direction to that of the lighter component through the series of vessels to the vessel M1 as shown by the unbroken arrow lines.

Continuous operation is maintained by supplying the two components steadily at appropriate rates. The counter-current displacement vessels C1 to C5 operate as spray columns with a continuous phase and a discontinuous phase in droplet or particulate form and there is no separation in the vessels into two separate layers more than any slight inadvertent accumulation of a heavier continuous phase in the lower corners of the counter-current displacement vessels.

When the denser component is the continuous phase, the lighter component is dispersed throughout the mixing vessels, and some of the mixture is swept through the lower openings into the less agitated region at the base of the counter-current displacement vessels. Here the lighter component liquid droplets or solid particles are displaced upwards through the denser continuous phase component, whilst the latter is displaced downwards.

When the lighter component of the liquid system is the continuous phase, the more dense droplets in that portion of the mixture in each mixing vessel which is swept through the upper opening to the adjacent counter-current displacement vessel become displaced downwards through the vessel, the lighter component as the continuous phase being displaced upwards. At the base of the vessel the droplets of the more dense component come into the zone of agitation from the adjacent mixing vessel which causes them to be swept through the lower connecting channel into the mixing vessel. This action at the base of counter-current displacement vessels may be assisted by sloping the bases of the vessels downwards towards the adjacent mixing vessels, and although not an essential feature of the design it can aid the action particularly where the displacement vessels are of large cross-sectional area or where the denser component is a particulate solid.

Because the counter-current displacement vessels also function as extraction or reaction units, the extraction or reaction stage efficiency, taking a mixer plus a displacement vessel as a single stage, normally exceeds 100%, the theoretical limit to a conventional mixer-separator stage in which the separator does not contribute to the extraction or reaction process.

The plant may be of any size, depending on the required residence time and number of stages required, but the following proportions of the plant shown in Figure 1 give satisfactory results under a wide range of conditions. Each mixing vessel has a square cross-section of unit width and a total height of two units. The liquid height is 1.75 units and the upper and lower communicating openings each have a height of 0.25 units. The size (the horizontal cross-sectional area) of the counter-current displacement vessels should be at least about half, and generally up to one-and-a-half times that of the mixer vessels as hereinafter described.

The maximum counter-current throughput rates are the flow rates at which complete separation of the components fails at the light component separator outlet. Failure is caused by a hold up of one or both the components in the plant, usually in the counter-current displacement vessels, to the extent where the separation fails in the end separators. The maximum throughput represents the limit of the counter-current action and may be likened to the "flooding" stage in a counter-current vertical tower extraction unit.

Operational results, which are generally applicable, have been obtained from a plant unit of the type shown in Figure 1 for the liquid systems water-carbon tetrachloride and water-paraffin with either one of each pair of components as the continuous phase.

These results show that the maximum throughput is substantially directly proportional to the cross-sectional area of the counter-current displacement vessel provided that this area is not less than about half and not more than about one-and-a-half times the cross-sectional area of the mixer vessels. The maximum throughput depends upon the relative concentration of the two phases and for the above systems maximum throughputs have been obtained ranging from about 20 to about 150 cubic feet/hour for each square foot of cross-sectional area of a counter-current displacement vessel.

The maximum throughput is largely independent of the number of stages and of the size of the mixer vessels provided their size is related to that of the counter-current displacement vessels as given above. By experiments on small plant the plant size required for any throughput can thus be readily determined. The operational throughput should be of the order of half the maximum throughput.

For plant of any of the types shown in Figure 1, Figure 2 or Figure 3 operation may be commenced by filling the plant with the continuous phase component before commencing the steady supply of the two components and starting the mixer agitators. When this method of starting is employed the level of the liquid surface along the plant

usually slopes upwards from the denser component feed inlet to the lighter component feed inlet. The gradient of the surface slope gradually diminishes until the liquid surface throughout the mixing and counter-current displacement vessels is level demonstrating the uniformity of the counter-current flow conditions once the operation is under way.

When the lighter component is to be the continuous phase it will be necessary to shut off the heavy phase end separator outlet LH until sufficient of the heavier component accumulates to form a seal in the separator SH.

If undesirable solid by-products are formed by chemical interaction between the two components these by-products will not accumulate in the various counter-current displacement vessels but will pass along the plant to the end separators where arrangements may be made for their removal.

The mixing and counter-current displacement vessels may be provided with heating or cooling coils or jackets as required, and the vessels may be closed or covered tanks instead of open vessels.

The invention is not restricted in its application to straight forward continuous counter-current operations such as those described with reference to the drawings, but is applicable, with the introduction of inlet and outlet pipes to the appropriate vessels, to two or more successive separate, operations which may include co-current as well as counter-current operations carried out on one of the components in liquid out on ticulate solid form, the other component varying in different sections of the plant, and being fed into or withdrawn from various sections of the plant as required for the particular series of operations. These additional inlet or outlet pipes are not, of course, inter-connecting openings between mixing and counter-current displacement vessels.

WHAT I CLAIM IS:—

1. Apparatus for counter-currently contacting two immiscible or at least partly immiscible components of different densities, one component being a liquid and the other being a second liquid or a particulate solid, and comprising a single series of inter-connected vessels which may be filled with the components and which are alternately mixing vessels and upright counter-current displacement vessels, each mixing vessel having only two inter-connecting openings of which a lower opening connects the base region of each mixing vessel to the base region of the adjacent counter-current displacement vessel in the series in one direction and an upper opening connects each mixing vessel to its adjacent counter-current displacement vessel in the series in the other direction near to the level of the liquid surface when in the vessels, and a mixing device in each mixing vessel for mixing the components throughout the whole height of the mixing vessels whereby in operation the mixed components are swept through the inter-connecting openings into and across the adjacent counter - current displacement vessels and counter-current displacement of the two components takes place in the counter-current displacement vessels by counter-current movement of droplets or particles of one component distributed freely in the other component so that the two components are displaced through the series of vessels in opposite directions.

2. Apparatus for counter-currently contacting two immiscible or at least partly immiscible components of different densities, one component being a liquid and the other being a second liquid or a particulate solid, and comprising a single rectangular tank having a series of upright walls in parallel across the width of the tank which divides the tank into a single series of inter-connected vessels which may be filled with the components and which are alternately mixing vessels and counter-current displacement vessels, each mixing vessel having only two inter-connecting openings of which a lower opening in or under an upright wall in the series connects the base region of each mixing vessel and the base region of the counter-current displacement vessel adjacent in the series in one direction and an upper opening in or above an alternate upright wall in the series connects the region near the liquid surface when in each mixing vessel and the other counter-current displacement vessel adjacent in the series in the other direction, and a mixing device in each mixing vessel for mixing the components throughout the whole height of the mixing vessels whereby in operation the mixed components are swept through the inter-connecting openings into and across the adjacent counter-current displacement vessels and counter-current displacement of the two components takes place in the counter-current displacement vessels by counter-current movement of droplets or particles of one component distributed freely in the other component so that the two components are displaced through the series of vessels in opposite directions.

3. Apparatus according to either preceding claim and in which the size of each counter-current displacement vessel is between a half and one-and-a-half times the size of each mixing vessel.

4. Apparatus according to any preceding claim and in which the mixing device in each mixing vessel is a centrally situated agitator which does not impart more than a

slight overall up or down movement to the contents of the vessel.

5. Apparatus according to Claim 4 in which the agitator is an impeller which is arranged to rotate on a vertical axis and is arranged in operation to rotate at a speed in revolutions per minute which is of the order of 200/the average horizontal distance in feet across the mixing vessel.

6. Apparatus for counter-currently contacting two immiscible or at least partly immiscible components substantially as hereinbefore described with reference to Figure 1, Figure 2 or Figure 3 of the drawings accompanying the Provisional Specification.

J. V. GOODFELLOW,
Chartered Patent Agent,
Agent for the Applicant.

PROVISIONAL SPECIFICATION.

Apparatus for Contacting a Liquid with a Liquid or a Particulate Solid.

I, Minister of Supply, London, do hereby declare this invention to be described in the following statement:—

The present invention relates to apparatus which provides for the contacting of two immiscible or partly immiscible liquids or of a liquid with a solid in partcle form as occurs for example in leaching or extraction, washing or chemical reaction processes. The invention is concerned with apparatus of this type in which the desired interaction between the two components takes place by means of a counter-current flow of the two components in a series of alternate mixing and separating units arranged horizontally or substantially horizontally.

In the various forms of apparatus employing mixing and separating units which have been previously proposed or used, relatively complicated arrangements are used for pumping or raising the level of one of the components at various stages to maintain an onward flow of one or both of the components through the apparatus.

It is an object of the invention to provide for the contacting of two components in a counter-current liquid flow system, apparatus which does not employ any power-driven device (other than mixing devices in the mixing vessels) for maintaining the counter-current flow and which is relatively simple and compact in design and versatile and efficient in operation.

The present invention provides an apparatus having separation units in which the counter-current flow of the two components is arranged to take place without separation into two layers, functioning on the spray-tower principle with one component as a discontinuous phase passing as liquid droplets or solid particles through the other continuous phase component flowing counter-currently.

Each counter-current separation unit is arranged between two mixing vessels and is connected to one of the neighbouring mixing vessels at a low level so that the denser component which descends to the bottom of the separation unit may flow to this mixing vessel and each separation unit is connected to the other neighbouring mixing vessel at a high level so that the lighter component which rises to the top of the separation unit may flow to this other mixing vessel.

The counter-current flow in the separator units is a counter-displacement of the two components maintained by gravity, the denser component falling and the lighter component rising within the units until the connections to the adjacent mixing vessels are reached in each case. In the mixing vessels the counter-current flow is maintained by the action of simple stirring devices which, by intimately intermixing the contents, act to move the denser component upwards and move the lighter component downwards.

It is a fundamental feature of the invention that the mixing vessels and counter-current separator units are inter-connected and the mixing devices function so that the mixing action is effective throughout the whole height of each mixing vessel between its upper and lower inter-connections and causes the mixture to be swept through these inter-connections into the upper and lower regions of the connected counter-current separators. As a result the counter-current flow is made continuous from unit to unit.

Any desired number of alternate mixing and counter-current separation units may be connected in series so that with the surface of the liquid system at substantially the same level throughout, the denser component may pass in one direction through the series of units while the lighter component passes through in the opposite direction. Continuous operation of the apparatus may then be readily established by supplying the two components appropriate one at each end of the series of units and drawing off the components at the opposite ends after they have passed through the apparatus.

According to the invention, an apparatus for the interaction of a liquid system having two immiscible or at least partly immiscible components of different densities, one component beng a liquid and the other being a second liquid or a solid in particle form, comprises a series of substantially horizontally disposed inter-connected units all filled with the liquid system approximately to a given level, the units being alternately mixing vessels and counter-current separation units, a connecting channel being provided from the base region of each mixing vessel to the base region of the following separation unit in the series and a connecting channel being provided from near the surface of the liquid in each mixing vessel to near the surface of the liquid in the preceding separation unit, mixing devices being provided in each mixing vessel for mixing the components throughout the whole height of the mixing vessels from the lower to the upper connecting channel whereby the mixed components are swept across througn these channels into the adjacent separation units, counter-displacement of the two components without complete separation taking place in the separation units whereby the lighter component is displaced through the series of units in the forward direction from each unit to its following unit while the denser component is displaced through the series of units in the reverse direction. When the apparatus is operating continuously, the leading unit in the series is supplied with the lighter component while the last unit is supplied with the denser component, and the lighter component is drawn off from the last unit in the series while the denser component is drawn off from the leading unit.

The mixing vessels are provided with agitators such as flat gate-paddle impellers which do not produce any, or produce only a slight, resultant up or down movement of the liquid in the mixing vessels so that the onward movement of each component is not countered or is only partly countered.

Either the lighter or denser component may be the continuous phase of the system while the other component is the discontinuous phase, although if one component is a solid in particle form this would be the discontinuous phase.

The connecting channels between successive units in the plant may be in various forms which permit an adequate counter-current flow to take place. In a compact form of apparatus, adjacent units in the series are constructed with common walls and the channels are openings formed in the common walls. Alternatively, the adjacent units may consist of individual cylindrical or rectangular vessels connected together by short, straight pipes of rectangular or circular cross-section which form the connecting channels. In a further modification, each separation unit, with its connecting channels, is in the form of a single S-shaped pipe of suitable cross-sectional area, connecting the bottom of one mixing vessel with the top of the succeeding mixing vessel .

The separation units may take the form of simple unpacked spray columns, packed towers, orifice plate towers, or any suitable form of extraction tower in which the effect of gravity causes the denser component to be displaced downwards and the lighter component to be displaced upwards.

The invention and further features thereof will now be more particularly described by way of example in the course of the following description of three plants illustrated in Figures 1, 2 and 3 of the accompanying drawings.

The drawings are sectional elevational views of three of the many possible plant designs incorporating the fundamental principles of the invention.

Figure 1 illustrates a plant consisting essentially of a long rectangular vessel subdivided by vertical cross-walls or baffles into a series of vessels or compartments so that adjacent units in the series are constructed with common walls, and the connecting channels are openings formed in the common walls. These vessels are mixing vessels M1 to M5 which are positioned alternately with counter-current separators C1 to C4 acting as spray columns.

The baffle on one side of each mixing vessel M1 to M5 is curtailed as shown to form a rectangular opening linking the base of the mixing vessel with the base of the succeeding separator whereby the lower layers of liquid in the two vessels can intermix. On the opposite side of each mixing vessel the top of the baffle is curtailed to form an opening between the top of the mixing vessel and the top of the adjacent separators so that the surface layers can intermix.

Figure 2 illustrates a plant consisting of individual cylindrical or rectangular vessels forming alternate mixing and separation units linked together by short straight pipes of rectangular or circular cross-sections which form connecting channels between the base of each mixing vessel and the base of the succeeding separation unit, and between the upper region of each mixing vessel with the upper region of the preceding separation unit.

Figure 3 illustrates a similar plant modified so that each counter-current separation unit and its connecting channels is in the form of a single S-shaped pipe of suitable cross-sectional area, connecting the bottom of one mixing vessel with the upper region of the succeeding mixing vessel.

In both plants illustrated in Figures 2 and

3 the connecting channels between the mixing and separation units will need to be short and of sufficient cross-sectional area for the agitation in the mixing vessels to be carried across into the base and upper region of the appropriate neighbouring separation units.

In all three embodiments, the distribution of the discontinuous phase in the separation units may be assisted, especially in the case of unpacked units, by the addition of a suitably designed distributor, for example a perforated plate with an up or down comber, situated across the lower or upper regions of the separation units according to whether the lighter or heavier component respectively is the discontinuous phase.

The impellers for the mixing vessels should provide reasonably intimate mixing through the depth of the vessel without any marked resultant upward or downward bias. Flat-bladed turbine, or gate-paddle impellers may be used; flat small bladed turbine impellers operating at relatively high speeds being suitable where a high degree of agitation is required, while large flat gate-paddle impellers operating at low speeds are suitable where intimate mixing is not so essential to the process. In any case, reasonably uniform agitation is necessary vertically throughout the mixer contents for effective counter-current operation. In a plant using rectangular mixing vessels and common connecting walls as illustrated in Figure 1, single flat-bladed impellers situated centrally in the cross-sectional position and either centrally or slightly above, in the vertical direction in the mixer contents, are effective without any baffling. In the case of cylindrical mixing vessels, some form of baffling such as vertical baffling, is necessary which will not provide any marked upward or downward bias.

At each end of the series of vessels M1 to M5 and C1 to C4 in each plant are separating vessels SL and SH which are arranged to collect the lighter and denser fluid components respectively which are then drawn off through outlet pipes LL and LH respectively. End separating units of different design will be necessary in the case where one of the components is a solid in particle form.

With the end separator outlet pipes LL and LH at suitable heights, the plants can operate with either the heavier or lighter component as the continuous phase depending upon the relative concentration of the two components in the plant. The relative concentration depends upon a number of factors including the nature of the liquids, the size and shape of the counter-current separators and the connecting channels, and the action of the mixing impellers which may be arranged to slightly counter the flow of one component and so increase its concentration.

In all three plants the action is as follows. The lighter component is supplied to the mixing vessel M1 and passes in a forward direction through the series of vessels to the vessel M5 as shown by the broken arrow lines, while the heavier component is supplied to the mixing vessel M5 and passes in the reverse direction through the series of vessels to the vessel M1 as shown by the unbroken arrow lines.

Continuous operation is maintained by supplying the two components steadily at appropriate rates. The counter-current separation units C1 to C5 operate as spray columns with a continuous and discontinuous phase and there is no separation in the units into two separate layers.

In the case where the denser component of the liquid system is the continuous phase, the lighter component is dispersed throughout the mixing vessels, and some of the mixture is swept through the lower orifices into the less agitated region at the base of the separation units. Here the lighter component liquid droplets or solid particles are displaced upwards through the denser continuous phase component, whilst the latter is displaced downwards. This downwards displacement of the denser component probably accounts very largely for its counter-current passage through the plant, as in operation, no head gradient is apparent in the plant once equilibrium conditions have been obtained.

In the case where the lighter component of the liquid system is the continuous phase, the more dense droplets in that portion of the mixture in each mixing vessel which is swept through the upper opening to the adjacent separation unit become displaced downwards through the unit, the lighter component as the continuous phase being displaced upwards. At the base of the unit the droplets of the more dense component come into the zone of agitation from the adjacent mixing vessel which causes them to be swept through the lower connecting channel into the mixing vessel. This action at the base of the separation units may be assisted by sloping the bases of the units and/or the connecting channels, towards the adjacent mixing vessels, and although not an essential feature of the design it can aid the action particularly where the separation units are of large cross-sectional area or where the denser component is a solid in particle form.

For plant of any of the types shown in Figure 1, Figure 2 or Figure 3 operation may be commenced by filling the plant with the continuous phase component before commencing the steady supply of the two components and starting the mixer agitators.

When this method of starting is employed the liquid surface along the plant usually shows a gradient rising from the denser component feed inlet to the lighter component feed inlet. This gradient gradually diminishes until the liquid surface throughout the mixing and separation units is level demonstrating the uniformity of the counter-current flow conditions once the operation is under way.

When the lighter component is to be the continuous phase it will be necessary to shut off the heavy phase end separator outlet LH until sufficient of the heavier component accumulates to form a seal in the separator SH.

If undesirable solid by-products are formed by chemical interaction between the two components these by-products will not accumulate in the various separation units but will pass along the plant to the end separating units where arrangements may be made for their removal.

The mixing and separation units may be provided with heating or cooling coils or jackets as required, and the units may be closed or covered tanks instead of open vessels.

The invention is not restricted in its application to straight forward continuous counter-current operations such as those described with reference to the drawings, but is applicable, with the introduction of outlet pipes to the appropriate separation units, to two or more successive separate, co-current or counter-current operations carried out on one of the components in liquid or particulate solid form, the other component varying in different sections of the plant, and being fed into or withdrawn from various sections of the plant as required for the particular series of operations.

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FIG. 1

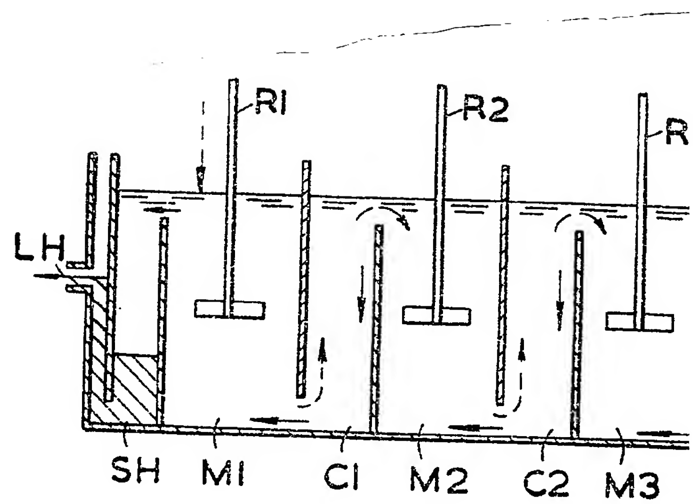


FIG. 2

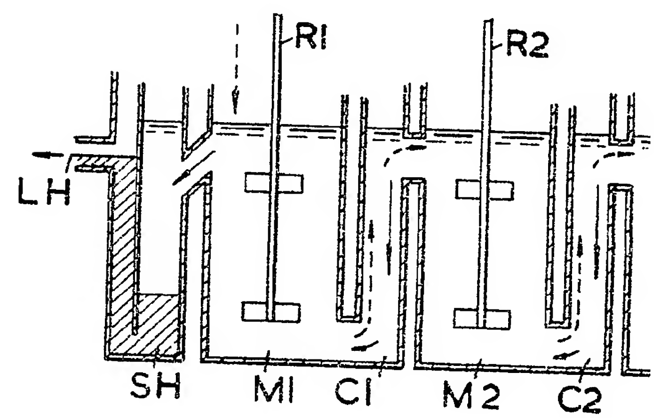
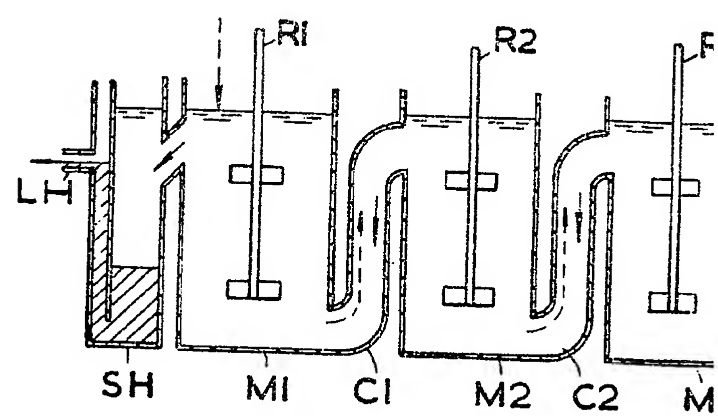


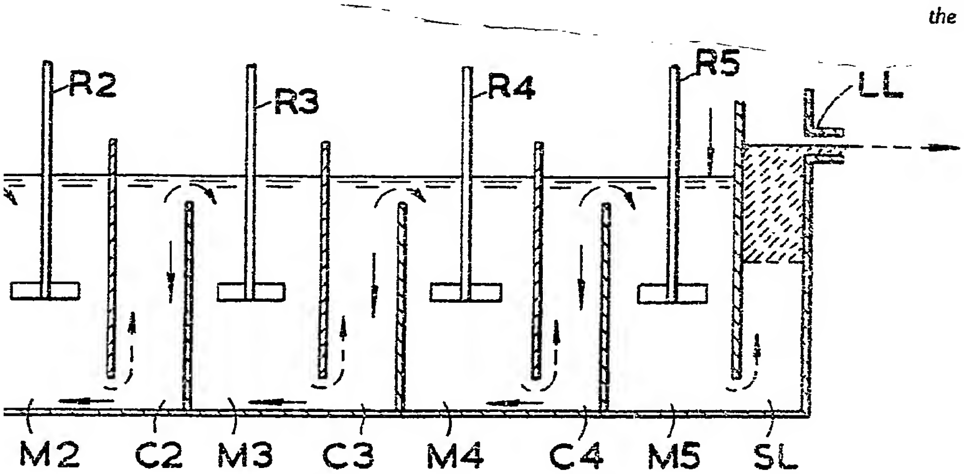
FIG. 3

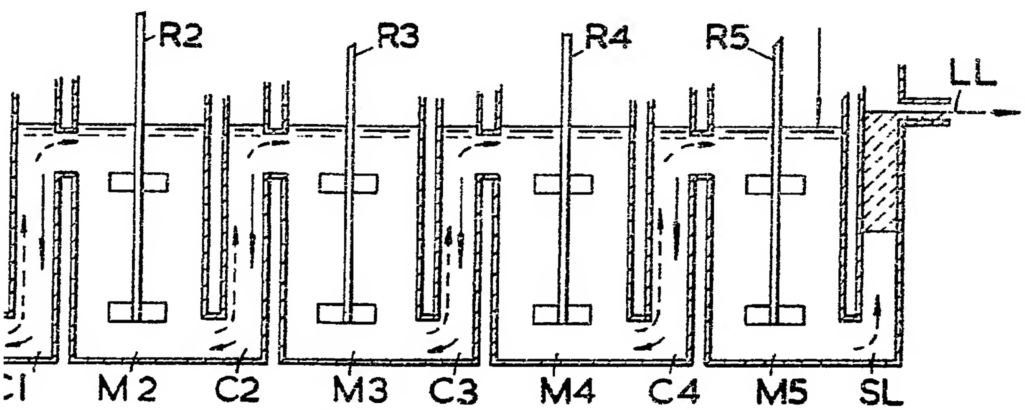


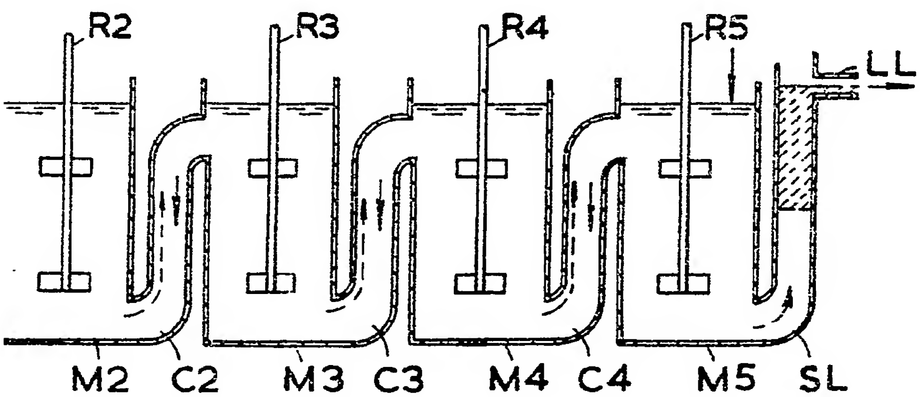
885,503 PROVISIONAL SPECIFICATION

1 SHEET

This drawing is a reproduction of the Original on a reduced scale.







885,503 PROVISIONAL SPECIFICATION

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FIG. 1

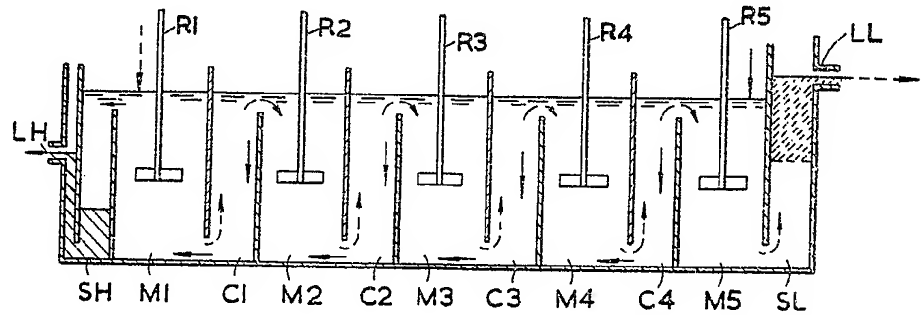

FIG. 2

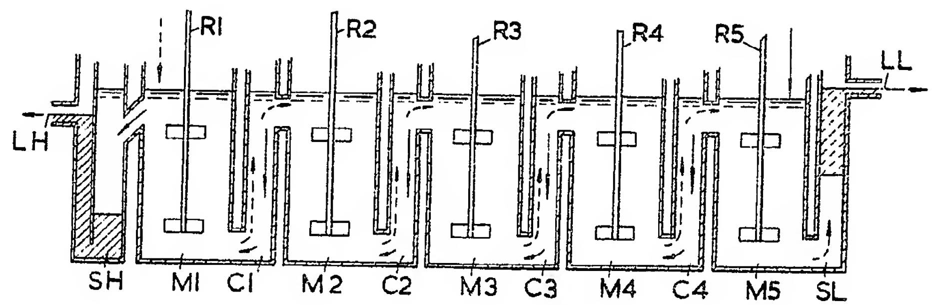

FIG. 3